THE DETERMINATION OF AGE AND GROWTH OF FISHES OF TROPICAL AND SUB-TROPICAL WATERS[1]

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In modern fishery investigation the determination of the age and rate of growth of fish occupies a very important place, since the knowledge of the age and growth is of notable significance from both scientific and commercial aspects. The evaluation of age provides a means to understand the composition of a fish population with regard to the age classes and to find the role of particular year classes in the fluctuations of the stock. The study of the growth-rate of fish leads to an effective and conclusive assessment of the sustaining power of the stock in a fishery, viz., a stock of fast growing fish can sustain a more intensive fishery than one of slow growth by its ability for fast recuperation. The determination of the rate of mortality of the different year classes, their survival rate and success of the individual year broods, that are of fundamental importance in the forecast and scientific exploitation of a fishery, are based on the knowledge of the age and growth-rate of the fish. The beginning of this century saw Norwegian workers engaged in a detailed study of the age and growth-rate of commercially important fishes like the Cod, Herring and Salmon. This was followed by several fishery workers in Europe and America working on many commercial and non-commercial fishes. Based on a detailed study of the age and growth-rate and the fluctuation of year classes in the population, short-term forecasts are made in recent years with reference to fish whose biology has been fully studied.

All this development in fishery research has been so far restricted to the temperate waters. There have been a few individual attempts to determine the age and growth-rate of some fishes in tropical and sub-tropical waters. An attempt is made in this paper to review this work.

AGE INDICES

The principle of age determination in fishes depends on the 'annual' growth marks that are formed in certain skeletal parts of fish, like the scales, otoliths and bones. These growth marks are really the growth checks formed on skeletal parts as a result of fluctuations in the growth of the fish. The growth of a fish, normally, is not uniform throughout the year or its life. The fish grows fast during a certain part of the year and slower or even ceases to grow during another part of the year. This fluctuating periodicity of fast and slow growth of the fish expresses itself annually on the skeletal parts of the fish as a periodic structure of fast growing (i.e., wide) and slow growing (i.e., narrow) zones. On the scales

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the fast growing zones are represented by wider sclerites or circulii and the slow growing zones by narrow sclerites arranged very close together in the form of bands or rings. The fast growing zones on the otoliths and bones are broad, opaque and white regions and the slow growing zones are narrow, thin and transparent ones. European and American ichthyologists have more or less established that these rhythms of growth are seasonal and that there is a very close relation between the periodic structure of the skeletal parts and the growth of the fish. The difference of opinion amongst the various workers has been mainly on two questions.

1. In several instances the skeletal structures show some secondary rings besides the normal 'annual rings'. The doubt has been as to the qualifying characters of an annual ring and a secondary ring.

2. The causative factors that are responsible for the formation of the growth checks or the 'annual rings' on the skeletal parts of the fish are still not known.

Monastuirsky (1926), Graham (1929), Van Oosten (1929) and Menon (1950) have reviewed the opinions of various workers on the first question.

Causative Factors in the Formation of the 'Annual Rings'

A short summary of the interesting observations on the second question is given below since it is important to postulate the utility of the skeletal parts of tropical fishes in the evaluation of their age.

It has frequently been assumed that growth-rate is greater during the period of higher temperature. Lea (1911) observed in the young herring that the rate of increase in length deduced from the scales was greatest when there was a rise of temperature in spring but it fell off before the temperature attained its maximum. Fraser (1917) also made a similar observation in *Onchorhynchus tschawytscha*. Experimental work has been reported by Fulton (1904), Cutler (1918), Dannevig (1925), Thompson (1920), Gray and Setna (1931), Brown (1946) and Molander (1947). Fulton (1904) noticed that the growth-rate increased in fish kept in warm tanks during the winter. But Cunningham (1905) examined the scales of a whiting from Fulton's experiments and found that although this fish had been kept in a warm tank during the winter, 'the winter ring was recorded on the scale'. Cutler (1918) found that temperature was a controlling factor of sclerite width in the scales of *Pleuronectes*. A higher temperature produced wider sclerites corresponding to the so-called summer zone of the scale and lower temperature produced narrow sclerites or the winter zone of the scale. The experiments of Dannevig (1925), gave just the contrary results, that the sclerite width was greater at lower temperature and lower feeding. Dannevig (1925), Thompson (1926) and Graham (1929) observed that there was a marked correlation between sclerite width and growth-rate. Graham (1929) also suggested that 'the main maximum of growth-rate (with high sclerite width) is an inherent rhythmical response'.

No well defined summer or winter zones were noticed by Gray and Setna (1931) on the scales of *Salmo irideus* that had been fed continuously throughout the year. 'This fact seems to eliminate the suggestion that the periodicity of the circulus width found in other members of the *Salmonid* family under natural conditions is due to an inherent rhythm over which the environment has no control. It also suggests that temperature alone is not invariably a decisive factor.' They also found that abundant food could effect an increased growth-rate and that wide rings (summer rings) could be formed in winter as well. The scarcity of food caused a reduction in the ring width. Hoffbauer (1899) and Thomson (1904) attributed the formation of the annual rings on the scales to the variations in food supply. Dannevig (1925) found that the wider sclerites were formed in winter and narrow ones in summer. According to Duff (1929) there was a drop in the growth of the scales and the production of the circulii during the period of most rapid growth of fish and he attributed it to the diversion of energy to other parts of the body during the growth in length of the fish. Duff put forward a hypothesis that there is no growth of fish or scale in winter and the zone of broad circulii is formed during the first half and the zone of narrow circulii during the latter half of the growth season.

The assumption by Gray and Setna (1931) that the periodicity of an inherent rhythm has no part in the periodicity of the scale growth does not hold good for the brown trout (*Salmo trutta*) in which Brown (1946) found that the annual cycle of growth was clearly expressed on the scale with an autumn check. Brown observed that this was presumably the result of an annual physiological cycle of changes in the internal environment, possibly the variation of the secretion of an endocrine organ such as the pituitary gland . . . . 'Since this cycle occurred in the absence of variation of any environmental factor, it cannot depend on the existence of environmental time markers.'

The brown trout kept under controlled conditions became sexually mature at the same age and season as those of the same stock kept under natural conditions.

Hickling (1933) also held more or less similar opinion in his study of the hake in which he attributed the formation of the transparent zones on the otoliths to a physiological rhythm, they being laid down during the period of greatest physiological stress. 'In the mature fish this is the exhaustion due to spawning and in immature fish to its precursor in the innate physiological rhythm which can be detected in the somatic tissues.'

Molander (1947) made a detailed study on the formation of the annual rings in the otolith of the plaice under controlled hydrographical conditions in aquaria. He concluded that (1) 'the growth of the plaice is clearly less in an experimental aquarium with constant cold water than in one with constant warm water and (2) independent of the different hydrographic milieu in the cold and warm experimental aquarium, one finds in both aquaria a coincidental annual growth rhythm on the part of the plaice, which is reflected in the formation of the annual rings on the otoliths. This growth rhythm coincides with an annual rhythm in nutrient intake and is probably due to internal genetic causes.'

From the above it is clear that the causative factor in the formation of these growth checks is not yet very clear or conclusive. The main factor that emerges out of the experimental studies of Dannevig (1925), Thompson (1926), Gray and Setna (1931), Brown (1946) and Molander (1947), is that the role of temperature variations in the periodicity of the structure of the skeletal parts of the fish has been over-emphasised.

The narrow zones in the scales and otoliths of cod (Dannevig, 1933) and the transparent zones in the otoliths of hake (Hickling, 1933) and the supra-occipital crest of the Poor Cod (Menon, 1950 *b*) have been observed to be formed in the majority of the specimens during the latter part of the summer and autumn. In several other fishes these growth checks are laid down during the period of lowest temperature. This apparent contradiction in the relation of temperature to the formation of the annual growth checks itself throws doubt on the possible influence of temperature in the phenomenon of the periodicity of the structure of the skeletal parts of fish.

The role of the variations in food supply also appears to be indecisive. In *Salmo irideus*, Gray and Setna (1931) found that specimens which have been fed continuously throughout the year did not show any well defined summer and winter zones. Brown (1946) observed just the opposite, that, even in specimens kept under controlled temperature, food, light, flow of water, composition and aeration of water and amount of living space, the annual periodicity was markedly visible on the scales.

The observations of Graham (1929), Hickling (1933), Brown (1946), Molander (1947) and Menon (1950 *b*) suggest an inherent physiological rhythm as a more possible causative factor in the formation of the growth checks. Fage and Veillet (1938) suggested that the maturation of the gonads was generally followed by a decrease in the growth-rate. It has been noticed in several fishes that there is a decrease in the rate of feeding and amount of food consumed with the maturation of gonads (vide Hardy, 1924, Hickling, 1933, Menon, 1950 *b*). Food is an important factor in the growth of an organism and maturation of gonads is a momentous physiological event in the growth history of a fish. The reduced feeding and the maturation of the gonads occurring simultaneously may perhaps play a great and effective part in the periodic formation of the annual growth checks in the skeletal parts of the fish. In the Indian Chub Mackerel (*Rastrelliger kanagurta*) it was noticed that there was a decrease in the amount of food consumed with the progressive maturation of the gonads. Schneider (1910) has suggested that an internal factor is largely responsible for formation of rings in the scale of the herring. He defined this factor as the cessation of feeding at the spawning time 'associated with the drain on the reserves of the fish to supply material to the gonads; in short to a heavy excess of expenditure over income of materials' (Hickling, 1933).

Literature on the Age and Growth-rate of Tropical and Sub-tropical Fishes

That growth checks similar to those found in the temperate fishes occur in the skeletal parts of tropical and sub-tropical fishes has been more than sufficiently proved by Mohr (1910), Hornell and

Naidu (1924), Chevey (1930), Devanesan (1943) and Nair (1949). The validity and the interpretation of these growth checks or age indices remain to be decided. None of these workers examined the problem on the basis of the critical analysis enunciated by Graham (1929) and Van Oosten (1929) which alone can substantiate the validity of the annual nature of the growth checks that they all presupposed in their studies. Mohr (1921) investigated the age and growth-rate of *Rasbora vulgaris* from Kuala Lumpur, *R. elegans* from Kuala Jalai, *R. daniconius* from Vakvella, Ceylon, *Trichopodus trichopterus* from Kuala Lumpur, *Barillus guttatus* from Pahang River, *Ambassis commersonii* from a river in New Pommern and *Polynemus indicus* from the north coasts of New Pommern. There are marked climatic changes of rainy period and dry period in Ceylon whereas the temperature and climatic conditions are uniform throughout the year in the localities in Malaya from where the fishes were collected. The examined species included in them both fresh-water and marine forms having either cycloid or ctenoid scales. In all of them Mohr found very well defined scales showing distinct and sharp zones just as in the temperate fishes. Mohr did not explain the validity of the annual nature of the rings. But it is clear from the data given by him that increasing length groups of fish could be arranged in successive groups according to the number of rings. Mohr refuted the idea that the rings were only the results of seasonal changes and temperature fluctuations.

Whitehouse (1923) made some interesting observations on the growth-rate of the young fishes of the Silvatturai Lagoon in their first year by length measurements and following the Peterson method of size analysis. He investigated the monthly growth-rate of *Gerres lucidus*, *Teuthis java*, *Gobius criniger*, *Lutjanus quinquilinearis*, *Lethrinus cinereus* and *Equula edentula* during the first year of the life of the young ones in the lagoon. It is unfortunate that this interesting study was not continued for the larger size groups.

The detailed study of the life-history of the Indian Sardine (*Sardinella longiceps*) by Hornell and Naidu (1924) gives certain interesting details on the question of the age and rate of growth of the fish. They studied the rate of growth of the oil sardine by size analysis and computed the age by the Peterson method which was further substantiated by the scale reading. From these studies Hornell and Naidu gave the average life span of the oil sardine as 3 years, the lengths attained being 14, 15.5 and 16.4 cm. respectively. According to this the growth increments of the oil sardines are 14 cm., 1.5 cm. and 0.9 cm. in every succeeding year of life. It is rather surprising that the growth-rate diminishes at such an alarming rate. I feel that this calculation is questionable and erroneous. The error must have naturally been due to the fact that Hornell and Naidu did not examine fully developed scales. In the scalimetric study of the age of fishes, several workers (Thompson, 1922, Oosten, 1929 and Monastiursky, 1930) have shown clearly that scales from different parts of the body of the fish give very different and conflicting readings. It may be that Hornell and Naidu did not examine the scales from the same part of the body of the oil sardine in all the specimens.

Ranga Rao (1934) followed the Peterson method in determining the growth of *Therapon jarbua* (Day) collected in the estuaries of Adyar and Cooum and the sea at Madras. The details of his work remain unpublished. In the abstract of his paper he maintained that the fish migrates into the sea in its second year to attain sexual maturity and that the growth is greater in its second year during its life in the sea than in the first year in the brackish water. The growth was also found greatest during the colder months of December to January. During the summer months of April to July it was slowest.

The otolith was found very effective and useful in the determination of age and growth of *Psettodes erumei* (Bl. Schn.) by Ranga Rao (1935). Rao observed successive zones of growth on the otoliths and these were demarcated distinctly and clearly. Like Nair (1950) and Mohr (1910) Rao also presupposed without valid evidences that these zones were annual. But unlike these two, Rao observed that in most specimens the otoliths showed distinct beginnings of the opaque zone at the outer edges during August and September, which period was found to be the height of the feeding season. It is indeed a pity that this paper also, like the previous, is available only in its abstract condition. Due to the absence of the detailed paper the details of Rao's work remain unknown.

The age of the oil sardine was again studied in greater detail by Devanesan (1943). He examined the scales of the oil sardine from the pectoral region, unlike Hornell and Naidu (op. cit.), who collected the scales from the middle region. The scales were mounted in egg albumen and glycerine. Devanesan noted that the scale of oil sardine 'does not suffer so much from supernumerary rings as from suppression or obliteration of its so-called "Winter rings" '. Still, vestiges of these rings are visible on the scales from which the real nature of the ring could be reconstructed. The age reading became more difficult with older age groups due to the greater obliteration of the rings on the scales. Devanesan's study was only a preliminary investigation which yielded sufficient results for a more detailed analysis of the problem. He calculated the growth of the oil sardine graphically and estimated the sizes of seven year classes.

Hora and Nair (1940) studied the growth of *Hilsa ilisha* in its earlier phase of life by observation in the settling tanks of Pulta Water Works. They found that the rate of growth in the first three months was rapid and then it declined. The fish reached a size of 12 in. in 10 months. They also examined the scales of a few adult Hilsa from Allahabad and found that scales of specimens of about 304 mm. showed 4 or 3 rings, those of specimens of 200 mm. and less showed one or roughly two rings and specimens of about 235 mm. showed 2 to 3 rings. Hora and Nair also observed from the nature of the edge of the scales that in April and May the cessation of growth takes place and this they attributed to the possible effect of low water level and scarcity of food in the hot and dry months. Hora and Nair's work revealed that in the life-history of fish there is a seasonal rhythm of growth.

Chacko, Krishnamurthy and Zobairi (1948) working on *Hilsa ilisha* observed that on the scales of the fish occurring in the Godavary Delta there were transversely arranged radii, the number of which corresponded to the length of fish in inches. Based on Job's (1942) assumption that the Hilsa grew at the rate of 1 in. per month, they observed that one radius was laid down per month on the scale. It is possible that the formation of the radii is related to a monthly physiological rhythm depending on the tidal periodicity as in the case of the maturation of the gonads noted in *Leuresthes tenuis* by Clark (1925) and *Enchelyopus cimbrius* by Battle (1930). The conflicting part of the paper of Chacko, Krishnamurthy and Zobairi, however, is that in the published diagram of the Hilsa scale, they have shown some transverse lines marked as 'radii' and four horse-shoe shaped lines spaced more or less at equal distance which are denoted as growth rings. What are these radii? What are these growth rings? Are they annual or half-yearly 'growth rings' or are they some spawning checks or marks impressed on them by their annual migration from sea to fresh-water and *vice versa?* The point requires a very detailed study and clarification and until then the conclusion that the number of radii correspond to the length of the fish in inches has to be regarded as a pure accidental coincidence.

Nair (1949) found the otoliths very useful in the age studies of the oil sardine (*Sardinella longiceps*). He treated the otoliths in a successive series of alcohol and xylol and then mounted them in Canada Balsam. When viewed with reflected light, he observed the growth zones as alternating translucent dark zones and opaque white ones, parallel to the margin of the otoliths. False rings could be picked out by their line-like appearance and by their tendency to join a growth ring. Nair presumed that these rings were annual, formed probably during December to April when scarcity of planktonic food has been noted. He is of the opinion that the life of the oil sardine is 3 years only and concurs with the findings of Hornell and Naidu. No indications are given as to how he considers these rings as annual. Perhaps more information will be forthcoming in the detailed account he has promised to make available soon.

Chacko and Krishnamurthi (1950) in their further studies on *Hilsa ilisha* of Godavary clarified the significance of the 'growth rings' on the scales observed by them in their earlier studies (1949). According to them there is a period of starvation concurrent with the spawning act, and during this period there is a general absorption of all the tissues of the body, the scale also being affected by the formation of a ring. A ring on the scale thus denoted a period of spawning and from the number of rings present on the scale the number of times the fish spawned could be determined. They inferred from this growth ring count that Hilsa spawned for a maximum of eight times in its life. The ring could not be treated as an index of age as it was not yet ascertained whether the mature Hilsa bred once every year or not.

Chidambaram (1950) in his studies on the length frequency of the oil sardine (*Sardinella longiceps*) examined the question of age from the basis of the predominant size groups. Following the methods of Heincke and Lea he examined the fate of the three predominant size groups in this fishery from 1937-38 to 1942-43. Based on this study Chidambaram concludes that 'the life of the oil sardine is between

3 and 4 years, the average lengths of the oil sardine being 10.0, 14.5, 18.3 and 20.5 cm.' in the respective years.

Chacko and Dixitulu (1951) examined the smaller size groups of *Hilsa ilisha* and again reiterated the findings of Chacko *et al.* (1948) that in *Hilsa ilisha* there is one radius on the scale for every inch in growth of the fish.

Sundara Raj (1951) supported the findings of Chacko *et al.* (1948) in the use of radii of scales to determine the age of *Hilsa ilisha*. Adducing evidence from the scales of *Hilsa ilisha* collected from different parts of India, Raj ventured to suggest that since the number of transverse radii corresponded more or less with the size of fish in inches and since this relation was found to be fairly constant, 'the radii in Hilsa scales should be used for age determination'.

Jones and Menon (1951) found that the scales started formation in *Hilsa ilisha* when the fish was 21 mm. in length. Commenting on the work of Chacko *et al.* (1948) they remarked that there was no correlation between the number of radii and the length of fish in inches and that it was difficult to accept the relationship between these two factors as drawn by Chacko *et al.* (1948). Jones and Menon have made observations on the appearance of the number of radii on the scales during the growth of the *Hilsa ilisha* in its larval and post larval stages. They observed one distinct 'growth ring' and two incomplete rings on the scales of a fish of 213 mm. in length. Their significance was left uninterpreted.

In the studies of the age and growth rate of the Indian mackerel *Rastrelliger kanagurta*, Chidambaram and Krishnamurthy (1951) used the otoliths. The number of growth rings on the otoliths had a close relation with the size groups. It was found too difficult to read the number of rings in the otoliths of specimens of 20 cms. and more in length.

Seshappa and Bhimachar (1951) working on Malabar sole (*Cynoglossus semifasciatus*) made certain interesting observations. They found clear rings on the scale which, by observation of the marginal nature of the scales, were found to be annual. They concluded that the rings were formed under the influence of the south-west monsoon season and thought it appropriate to call the rings as 'monsoon rings'. They correlated the check in growth to the depletion of food in sea bottom and opined that 'the lack of food leading to starvation' was the main factor in the formation of the rings. The work is of special importance as for the first time in tropical fisheries research has a proper method been employed and effort made to fix the validity of the annual nature of the rings. Seshappa and Bhimachar also observed that the otoliths showed no rings.

I am giving an abstract of Chevey's papers towards the end of this communication because of the critical observations in them that are of special interest to the work in our region.

Chevey (1930 *a*, *b*, *c* and 1932) made an interesting study on the value of the method of age determination by scales as applied to the fishes of Indo-China, Cochin-China and Cambodia. He found concentric zones of growth in the samples of *Synagris japonicus*, *Scolopsis bimaculatus*, *S. vosmeri*, *Pristipoma argenteum* and *Sciaena vulgaris* collected from Tonking in North Annam. But the samples of the same species collected from Cochin-China did not reveal any such zones of growth. He interpreted this variation as due to the occurrence of a winter condition in Tonking area and its absence in Cochin-China. The temperature of the surface water in Tonking and North Annam seems to be 27°C. to 28°C. in summer and 23°C. to 24°C. in winter, 'a difference of 4°C. to 5°C. seems to be sufficient to provoke the slowing of growth in fish and the marking of the scales'. He observed a similar phenomenon in the regions around Cape Varella. The species caught near Cape Varella showed a regular and continuous growth. Chevey attributed this to the effect of the cold current coming from the north during the north-east monsoon affecting only the coastal regions and not the bay. But in Cochin-China the fishes from the mouth of the rivers Meking and Bassac showed clear growth rings on their scales, a feature quite different from his previous observations on the fishes from the adjacent oceanic areas of the same regions. The reason for this, according to Chevey, is that during October to March every year, as a result of heavy rains, 'the Meking and Bassac put into the sea an enormous quantity of nitrogenous food material which provoke the temporary yet very thick concentration of the whole marine population of the neighbourhood. It appears to me without doubt that this rhythm of concentration and dispersion of the food material of the fish gives the marks on the scales, increasing the growth if there is a concentration provoked by abundance of food material and slowing of growth with the phase of dispersion'.

This phenomenon concurrent with the 'flooding' of the waters was further observed by Chevey in all the fishes of the rivers of Cochin-China and Cambodia and of the Grand Lac where all the scales of *Cyclocheilichthys enoploides, Albulichthys krempfi, Leptobarbus hoeveni* and *Labeo pleurotaenia* showed marks of this periodic rhythm. Chevey stated that 'the stoppage of growth occurs with the lowering of the water, which is the winter for these fishes physiologically'. He made very interesting observations on the effect of the flooding of the Grand Lac and Tonle-Sap. He found that in the scales of fishes from both these fresh-water areas, the growth checks occurred with lowering of the water level and as this lowering of water level occurred only once every year these checks were valid indices of the age of the fishes. He compared the rate of growth of *Labeo chrysophekadion, Hampala macrolepidotus, Leptobarbus hoeveni, Cyclocheilichthys enoploides* and *Puntius bramoides* from these two regions by a study of their scales and found that the specimens from Grand Lac showed a faster growth rate than those from the other regions. The reason he gave was that the Grand Lac during the flooding season overflooded thick verdant forest regions which provided a large amount of nitrogenous material for an enrichment of the food of the fish, whereas the Tonle-Sap overflooded only the fringes of such regions without any opportunity of enriching the waters with nitrogenous material.

These observations are interesting as they definitely agree with the findings in the temperate regions, that the temperature alone plays only a very indirect if not insignificant part in the stimulation of the growth checks. It might be of interest to compare the conditions that Chevey gave for the Indo-Chinese waters with those occurring on the West Coast of Madras Presidency. Chidambaram and Menon (1946) and Jacob and Menon (1947) have shown that there is a marked seasonal fluctuation in the surface temperature, salinity, total volume of plankton, copepods and diatoms in the West Hill sea. During the first part of the period of the south-west monsoon all the above hydrographic and biotic factors are at their lowest values. 'The environmental conditions in the inshore area during monsoon months (June to August) are quite distinct from those during the other months of the year and are characterised by a sharp fall in salinity and temperature, a high turbidity and turbulence and above all by the sea bottom becoming severely depleted of the organisms' (Seshappa and Bhimachar, 1951). The plankton production increases steadily after this period and the diatoms have their maximum period in August-September immediately after the enrichment of the region with the nutrient salts carried into the sea by the rains of the previous period. Following the diatoms there is the copepod maximum in the succeeding month. With the onset of the dry period the surface temperature and salinity increase culminating in the high temperature and salinity conditions of the summer months when the plankton production is at its minimum. In the studies on the oil sardine (Hornell and Naidu, 1924 and Devanesan, 1943) and the mackerel (Jairam Naidu) it was shown that the actual growth of these fishes occurred during the months of August to December when the region is very rich with planktonic food material. Hornell and Naidu (1924) observed that there was complete cessation of growth in the oil sardine during the months, January to May, i.e., the summer months. It has also been observed (Devanesan and Chidambaram 1949) that in the majority of the investigated fishes of the West Coast the spawning occurs during the monsoonic months just prior to the months of planktonic abundance. It is thus noteworthy that this period just prior to the monsoonic months when growth is actually arrested most possibly due to the maturation of the gonads and further aided by the lack of sufficient food material and the immediately succeeding period of monsoonic months when the temperature is lowered by 4°C. to 6°C. and when the actual spawning occurs, have in them all the possible ecological and physiological factors to impress the effect of this annual rhythm on the skeletal parts of the fish.

The observations of Delsman (1929) and Hardenberg (1939) are very sceptical on the question of determination of age in tropical fishes by the methods established in other climes. In fact Delsman (1929) opined that due to the 'absence of summer and winter' which accounts for the 'absence of winter rings on the scales of sea fishes', 'a very valuable method in studying the biology of fishes must consequently be abandoned', Hardenberg (1938) dilated on this opinion further and stated that due to the absence of any periodicity, year rings could not be ascertained and thus neither the growth nor the age of a fish could be made out. Without detailed examination of this important problem on the lines suggested by Graham (1929) and Oosten (1929), it is not possible to accept the statements held out by Delsman (1929) and Hardenberg (1938). It is a well-known fact that the index for age determination varies from fish to fish. In some the scales are useful, in others otoliths and in some others some specific bone. It is to be regarded as highly injudicious to accept that the growth of a fish in the tropics is uniform and that there is no rhythm in its growth in the year. There is periodicity in the physico-chemical and biological factors of the tropical waters. There is a periodic rhythm of spawning. It is not possible in the face of the periodicity of these various factors to accept that there is no periodicity in growth alone. The work of Chevey, Mohr, Rao, Seshappa and Bhimachar and several others given above completely go against these suggestions of Delsman and Hardenberg.

A critical study of the method using scales, otoliths and bones of the fish simultaneously and on the lines suggested by Graham (1929) is absolutely necessary to decide its validity in tropical and sub-tropical waters. It is also of interest to note that the conditions in tropical waters are extremely useful to decide the issue of the causative factor for the formation of these growth checks.

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